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# THE GEOLOGY OF THE UPPER YARRA REGION, CENTRAL VICTORIA

By Bruce R. Moore

Geology Department, University of Melbourne

## Abstract

The structure of the Siluro-Devonian sediments of the area is given in detail. The complex domes and basins encountered, resulting from the variable fold plunges, were interpreted in the field by means of the new graphical method described.

The detailed stratigraphy of the region is given and the rock units of the St Clair, Matlock, Tanjil, and Upper Yarra formations are included. The Siluro-Devonian boundary is discussed and, on the basis of recent graptolite determinations by Professor Hermann Jaeger, the strata containing the *Monograptus-Baragwanathia* association are placed in the Devonian, as are the overlying *Panenka-Styliolina* beds.

Turbidity current deposition is indicated, with a constant movement of sediment from the W. The increased frequency of turbidites towards the top of section is attributed to the tectonic movements in the geosyncline in the initial stages of the formation of the Upper Yarra Anticlinorium. The origin of the *Panenka* beds is thought to be related to turbidity currents.

## Introduction and Previous Literature

The region mapped in the present survey consists principally of the Siluro-Devonian sediments in the basin of the Upper Yarra. Most of the detailed work was achieved in the vicinity of the Upper Yarra Dam, since the rugged terrain in the E. of the area made detailed mapping extremely difficult.

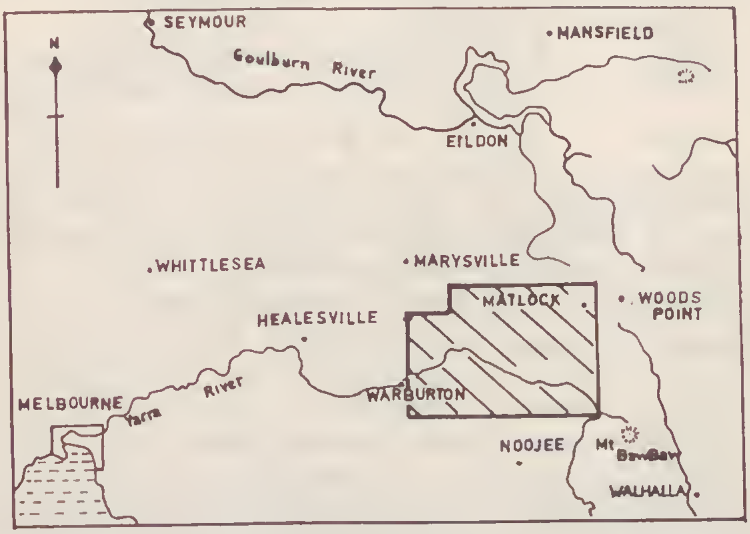


Fig. 1—Area Location.

The earlier mapped igneous boundaries were taken from the work of Hills and of Edwards for the Marysville Igneous Cauldron Subsidences and the Warburton areas respectively. The mapping was extended to the E. to join the work of Harris and Thomas (1947) on the strike faulted boundary between the Ordovician and Silurian sediments at Matlock. Detailed structural interpretation of the area, together with close definition of the rock units and sedimentation, was necessary in view of the unfossiliferous nature of the sediments.

Numerous small reports on the mines of the area constitute the earliest literature. In the first major contribution, Whitelaw determined the stratigraphical sequence of the area, describing the major rock units. It was obvious from his work that the succession E. of the doubly synclinal Walhalla Synclinorium differed markedly from that to the W. Inliers of Upper Ordovician sediments, monoclinal folds, and extensive gold deposits were described.

The Baragwanath memoir (1925) on the Aberfeldy District gave a comprehensive description of the geology of the area S. of that described by Whitelaw. He established that the Tertiary gravels occurring at different levels throughout the area were deposited during uplift and were not the result of uplift. He determind the extension of the basal grits of the Walhalla beds and their relationship to the other coarse grits in the section and described the Baw Baw Granodiorite and its contact zone.

Edwards (1932) described the igneous rocks of the Warburton district and discussed the petrogenesis of the Warburton Granodiorite, related dykes, and the Dacite suite.

Relationships between the Warburton Granodiorite and the Tynong Granite were discussed in a paper by Baker, Gordon, and Rowe (1939). Clear evidence was cited to show that the granite was intrusive into the granodiorite.

The major contributor to the geological knowledge of the area was Thomas (1937-1961), partly in collaboration with Harris. The basic elements of the stratigraphy of the Siluro-Devonian sediments of the East Central Victoria were outlined, the main marker horizons were indicated and an attempt made at correlation. The main subdivisions used by Harris and Thomas were:

| | | |
|---|---|---|
| Devonian | Lower | Walhalla Beds |
| | Upper | Tanjilian, including the *Panenka-Styliolina* beds |
| Silurian | Middle | Melbournian, including the *Monograptus-Baragwanathia* beds |
| | Lower | Keilorian, including the *Monograptus exiguus* band |

The importance of the *Panenka-Styliolina* association was discussed by Gill (1941); he considered some of the *Styliolina* occurrences to be of Yeringian (Lower Devonian) age, and some Upper Silurian. Philip (1960) suggested the top of the Tanjilian be taken as the Siluro-Devonian boundary.

The Marysville Igneous Complex, bounding the NW. corner of the present map, was described by Hills (1956). The existence of the two major cauldrons was explained, together with the mechanism of subsidence relating to the surrounding ring dykes.

## Structure

### Method of Interpretation of the Plunging Folds

Early in this survey, the author realized the complexity of the outcrop patterns produced by changes of plunge in the many close folds. The normal methods of plunge determination proved to be too slow, and necessitated too many observations for satisfactory use in the field. Since the marker horizons are generally concealed and of small thickness, the mountainous terrain and the changes of plunge made their outcrops difficult to trace.

The author (1964 MS.) has described a graphical method of rapid plunge determination and predicting the outcrop of such beds in the field. The method was developed by isolating a mathematical function, relating the normal field measurements of dip, strike, and plunge of the strata. The deviation in strike of the strata on the two limbs of the plunging fold was expressed as one half of the angle between the two strikes. This deviation was found to be related to the dip and strike of the strata by an arsin function.

A family of curves was plotted for the relationship between the strike deviation for values of dip at 5° intervals. From these curves the plunge of the beds could be very quickly determined by taking the normal measurements of dip and strike. This makes possible the accurate determination of the plunge of a fold even though it may be constantly changing.

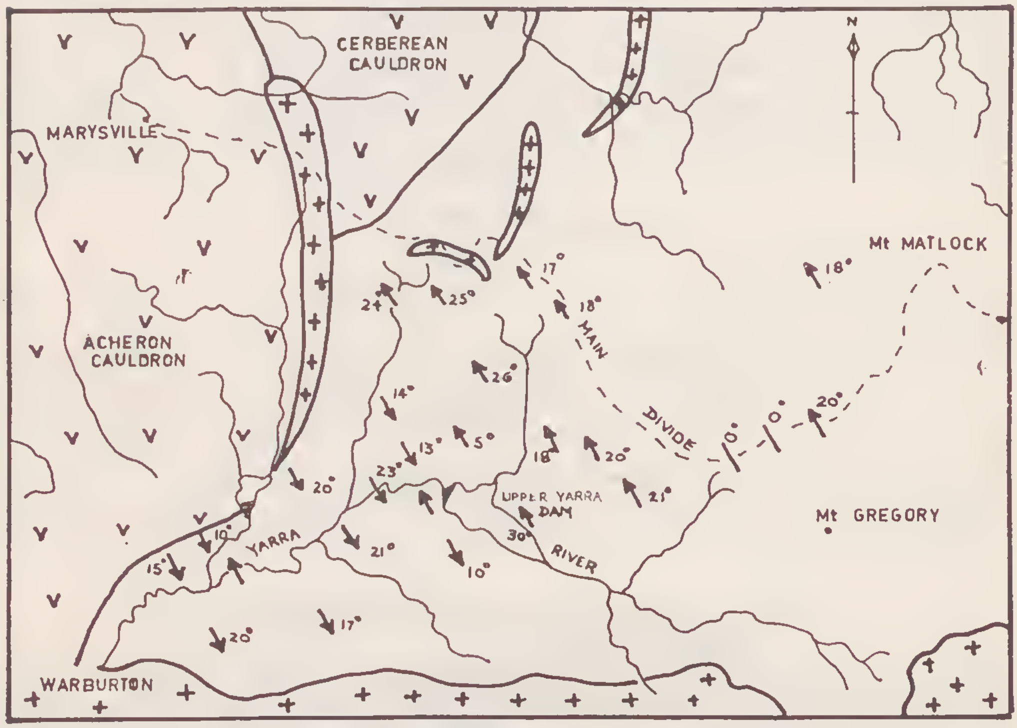


Fig. 2—Analysis of Plunge Directions.

An accurate value of the plunge of the fold is necessary to predict the outcrop of a marker horizon when dealing with severely undulating ground. By the use of the graph of a function relating plunge of the fold, determined by the above method, to the variation in contour height of the two stations, a correction could be applied to theoretical outcrop so that the strata could be located in the field.

This method was used with complete success in mountainous terrain where outcrops were concealed for considerable distances. In repeated cases, where outcrop was covered for distances of up to 2 miles, the new outcrop could be predicted to within 100 yds.

## General Structure

The area is dominated by the Upper Yarra Anticlinorium some 20 miles in breadth, separated from the Walhalla Synclinorium to the E. by several broad simple folds in the vicinity of Matlock. The structures superimposed on this anticlinorium are second order folds consisting of minor anticlinoria and synclinoria with crests from 1-3 miles apart. These folds in turn are composed of third order anticlines and synclines with crests from 50 yds to ½ mile apart.

E. of Monty's Camp, the section is composed of broad anticlines and synclines, which are deep structures containing the greatest thickness of sediments preserved in the area. The major folds axes are shown in Fig. 4. These fold axes of the Monty's Camp Syncline, the Forest Camp Anticline, the Oaks Syncline, and the St Clair Anticline, are spaced at intervals of 3-4 miles; this contrasts with the close fold spacing of the Upper Yarra Anticlinorium.

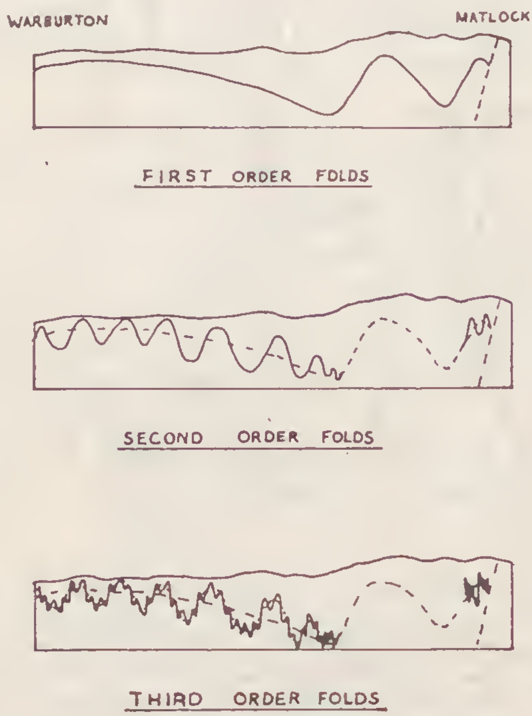


FIG. 3—Theoretical Folding Analysis.

The limbs of most of the folds in the area have an average dip of 60-70°. The true strike of the sediments varies between N.310 E. and N.340 E., showing a slight convex curve towards the Warburton area. The strong plunges of the folds cause marked deviations from these values in the field, with plunges of 10-35° being common. The resulting outcrops of the domes and basins produce a zig zag pattern of outcrop in the closely folded regions.

The fold pattern of the Upper Yarra Anticlinorium causes repetition of the fossiliferous horizons of the Tanjil Formation W. of the Upper Yarra Dam. These outcrops are repeats of the strata to the E. at Matlock and the old 18 Mile Quarry on the Yarra Track.

Thomas (1947) mapped the boundaries of the Silurian and Upper Ordovician as a series of strike faulted contacts. The present survey adjoins the most westerly of these contacts at McAdam's Hill. No evidence was found modifying the maps and sections of Thomas; these have been included in the E. portions of the accompanying map and section.

### Details of the Section

Near Warburton, the sediments are concealed by the detrital deposits from the dacite mass to the N. Nevertheless, evidence for the existence of the Warburton Syncline can be seen in road cuttings S. of the Yarra, also on the Donna Buang Road to the N. The Braham's Creek Syncline is the dominant structure in the East Warburton area, causing repetition of the current bedded Upper Yarra Formation, so prominent on the Reefton Spur Road some 10 miles to the E. The Starvation Creek Anticline is flanked by many close folds causing the *Panenka* beds marker horizon to outcrop at the junction of Starvation Ck and the Yarra R. Prominent cleavage has developed in the blue slates close to the fold axis. Both the Braham's Creek Syncline and the Starvation Creek Anticline show well defined plunges of 25° and 16°, respectively, away from the Acheron Dacite Cauldron; the origin of these plunges will be discussed later.

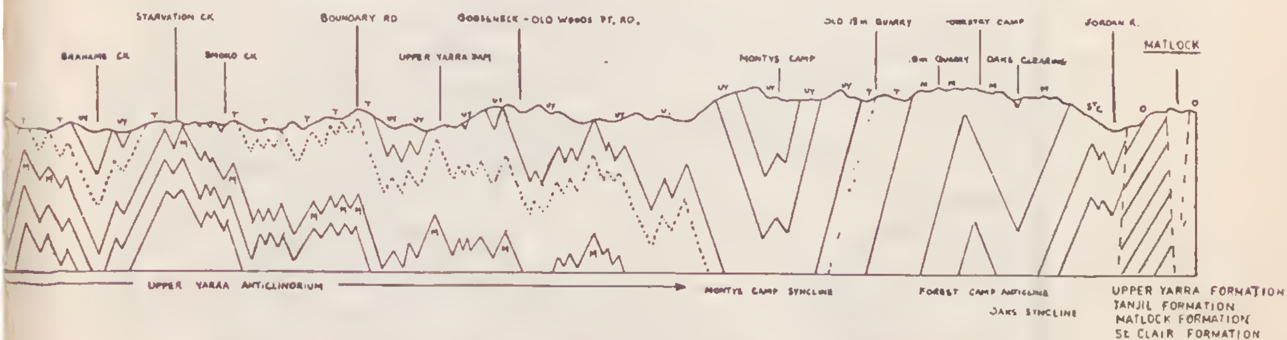


FIG. 4—General Geological Section of the Upper Yarra Region.

A well defined crush zone appears in the section at Reefton, where numerous close repeats of the strata are disclosed. The crush zone lies on a southerly extension of the boundary of the Acheron and Cerberean cauldrons, marked by a prominent ring dyke (Hills 1956). This crush zone marks the point at which the fold plunges change from a southerly direction at East Warburton to a northerly direction at the Upper Yarra Dam. This crush zone possibly reflects bedrock movements associated with the cauldrons. Numerous small folds are present in the section at Muddy Ck, McMahon's Ck, and at Reefton. In this part of the section E. of Reefton, Gill (1942) located a limited horizon with a brachiopod fauna resembling the Yeringian fauna in many respects. This horizon lies immediately above the *Panenka* Beds. There is also a close association of plant remains (including *Hostimella*) with the *Panenka* Beds in this part of the section.

The Yankee Jim Anticline is notable for the reversal of plunge occurring along its axis. On the N. side of the Yarra the plunge is 14-18° to the S., changing to 12° at the Yankee Jim Quarry on the Main Road; farther to the S., on Boundary R, the plunge reverts to 10° S. The complicated outcrop patterns produced by these plunges and reversals will be discussed later.

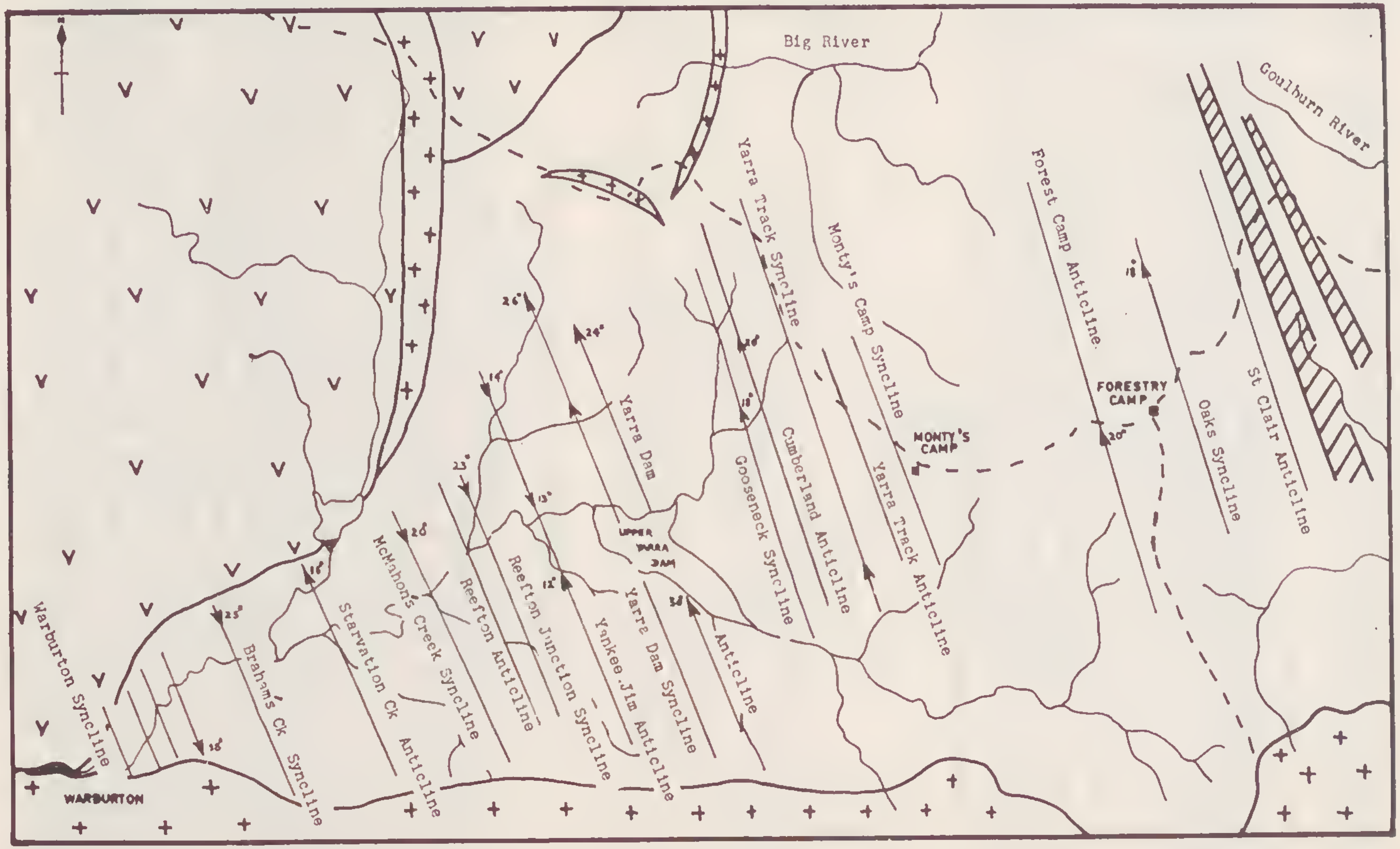


FIG. 5—Major Axial Lines.

E. of the Yankee Jim Anticline, the strata dip to the double synclinal structure of the Upper Yarra Dam itself. The folds terminate in the ring dykes and cauldrons of the Cerberean Cauldron. It is most noticeable that, E. of the large ring dyke marking the margin of the Acheron Cauldron, the plunge of the sediments changes to a northerly direction towards the Cerberean Cauldron. This northerly plunge is maintained in all the major folds N. and E. of the Upper Yarra Dam.

The Gooseneck Syncline is a prominent feature which extends a considerable distance along the strike of the sediments. The structure is seen in the vicinity of the Gooseneck on the Old Woods Point Rd. It is seen again on the new Board of Works access road from the Walsh's Ck Arm of the Dam to the Yarra Track. The structure continues N. to outcrop on the Yarra Track near Cumberland Junction. The plunge of the fold is 23° N. at the Gooseneck, then 18° N. on the Walsh's Ck Rd and 21° N. at the intersection of the fold with the Yarra Track.

E. of the Cumberland Anticline greater thicknesses of Devonian sediment appear in the section, as the Upper Yarra Anticlinorium dips E. towards the Monty's Camp Syncline. The Cumberland Anticline has minor folds on both its flanks, being separated from the large Monty's Camp Syncline by the smaller Yarra Track Syncline and Anticline. These folds can be seen on the Yarra Track but their southerly extension to the Old Woods Point Rd is obscured by soil.

The Monty's Camp Syncline, possibly the most important structure in the section, is over 5 miles in width, and contains the greatest development of sediment in the area. The youngest Devonian sediments are exposd at Monty's Camp itself; between this point and the Forest Camp Anticline almost all the Upper Yarra, Tanjil, and Matlock formations are exposed. Outcrops of the limbs of this fold are discontinuous, but available exposures show it to be of simple form, with dips of 60-70°, giving a total thickness of 18,000 ft of sediment.

Due to lack of exposures, the exact position of the axis of the Forest Camp Anticline is difficult to ascertain on the Yarra Track. A more accurate idea of the fold is obtained 5 miles to the N. on Frenchman's Track where it plunges N. at 32°; the same fold on the Yarra Track has a plunge of 10° to the N.

It is noticeable that both the major folds of the region, the Monty's Camp Syncline and the Forest Camp Anticline, show less plunge to the S. on the Yarra Track. The former shows no plunge at Monty's Camp itself.

Both the Forest Camp Anticline and the St Clair Anticline to the E. are simple folds. Farther E., numerous small folds are encountered before the contact between Silurian and Upper Ordovician at McAdam's Hill is reached.

In general, it is noticeable that the folds in the E. of the area are very broad and simple, involving a large thickness of sediment. In contrast to this, the folds in the W., comprising the Upper Yarra Anticlinorium, are complex and closely situated. It is considered possible that the intensity of folding in the W. of the area is related to the plutons and volcanic cauldrons. A final conclusion cannot be reached until the current detailed mapping of the bedrock structure to the N. and W. of these cauldrons is completed. Nevertheless, this triangular area of sediments, bounded on the N. and W. by the cauldrons, and on the S. and W. by the plutons, has experienced the most intense folding in this region.

### Relation of the Plunge of the Sediments to the Cauldron

It is particularly noticeable that the plunges of the sediments in the vicinity of the Acheron Cauldron are generally in a southerly direction, whereas those close to the adjacent Cerberean Cauldron have a generally northerly trend.

It is also striking that the reversal in plunge of the surrounding sediments occurs at the junction of the two cauldrons. While no direct evidence linking the cauldron mechanism with the plunge of the bedrock was found it is considered that a relationship exists. While the movement of the basement within the confines of the cauldron would be vertically downwards, the bedrock outside the cauldrons could have been buckled in opposite directions giving the different plunges observed.

### Relation of the Structure to the Woods Point Dyke Swarm

This dyke swarm is of late Middle Devonian and early Upper Devonian age. It is made up of hundreds of acid dykes, stretching from Walhalla NW. of Eildon (Hills 1952). The present area, to the W. of the main swarm, had not been examined for dykes and an exhaustive search during the present survey revealed only a few small dykes, but no lateral extension of the swarm.

It is now clear that the dykes are confined to the belt of sediments E. of the line of the Baw Baw pluton and the Cerberean Cauldron. Some dykes were recorded S. of the Tynong Granite in the region of the Tanjil R. by Hills. These dykes were not found to continue N. of the granite into the present area. The strong lineation of the dykes closely follows the strike of the sediments in which they occupy fractures.

### Mechanism of the Folding

The exact stages in the formation of the folded structures in the area are difficult to reconstruct. A mechanism which would produce such persistent close folding in the W. of the area and broad open folding in the E. is unusual.

All major folds and many of the minor folds in the area show a remarkable persistence along strike and can be traced along their axes for distances of 10-15 miles. The angles of dip remain approximately constant but the plunges change frequently. Folds E. of the Upper Yarra Dam tend to show an arc-like sweep, convex towards Warburton.

A study of the sedimentation shows a constant westerly source direction for the Tanjil Formation and the overlying Upper Yarra Formation. The thickness of both these formations is less in the Warburton area than in the vicinity of Matlock. The sudden introduction of large scale turbidite sedimentation towards the top of the Tanjil Formation is interpreted as heralding the commencement of fold movements.

These first movements could have involved arching on the site of the Upper Yarra Anticlinorium. If this region began to rise before the Matlock region, this would explain the apparent resorting of sediment towards the E. in the Upper Yarra Formation. This is supported by further work to the W. of Warburton on the W. flank of the Upper Yarra Anticlinorium where sediment of a similar age to the above has moved in the opposite direction. This concept would imply a sea floor slope away from the axis of the Anticlinorium and a consequent gentle unconformity or offlap from bed to bed. Such a structure would be almost impossible to trace in the field without continuous outcrop of a particular bed.

A turbidite origin is suggested to account for the current-bedded structures in the Upper Yarra Formation but until further investigations are concluded it is not considered to be conclusive. The existence of a bottom slope at the time of deposition of the Upper Yarra Formation is indicated by directional studies on the sediment.

The earth movements were probably slow and continuous to the Middle and Upper Devonian and no pulsations of sedimentation are indicated. The final stage was the earth movement associated with the ring dykes and cauldrons.

## Stratigraphy

This study is made difficult throughout the area by the scarcity of fossils, and hence the lack of accurate marker beds. The original marker horizons used by Harris and Thomas in mapping neighbouring areas were found to apply with certain modifications.

The problem of the boundary between the Silurian and the Devonian has long been recognized as difficult in this area due to the lack of zone fossils. Harris and Thomas took the well-defined basal conglomerates and grits of the Walhalla Synclinorium as the base of the Walhalla Beds and took this as a convenient horizon to mark the base of the Lower Devonian. These conglomerates and grits are not present in the Warburton-Matlock area. Philip (1962) considers the basal conglomerates, limestones, and grits of the Walhalla Group in the Tyers R. area to be early Lower Devonian in age.

In the present area, in the absence of a suitable marker horizon, a formation of black slates 1500 ft above the *Panenka* Beds was taken to be equivalent to the Basal Grits of the Walhalla Group known to outcrop E. of the present area. This formation of black slates is clearly exposed 2 miles E. of Monty's Camp. It repeats again on the Old Woods Point Rd in the vicinity of the Gooseneck, to the W. of the Upper Yarra Dam on Boundary Rd, and again in the W. of the area in the Braham's Creek Syncline.

Whether or not this black slate formation at the top of the Tanjil Formation approximates the Siluro-Devonian Boundary will depend on more accurate determinations of the graptolites from within the Tanjil Formation. Specimens from the well known localities within this formation are at present under review.

The major formations in the Warburton-Matlock area are described below, and a tentative correlation table is given.

### The St. Clair Formation

These are the oldest Silurian sediments and outcrop adjacent to the strike fault W. of McAdam's Hill where they are typically represented by black slates. Thomas (1947) showed a *Monograptus exiguus* band in a sketch section of the area. In the present survey this band could not be located; no faunal list or locality was given by Thomas. I have taken the uppermost beds of the St Clair Formation to be the top of the black slates in this area, and the lower portion of the formation at least to be of Keilorian (Lower Silurian) age.

The St Clair Formation is represented by 2000 ft of black slates before the Upper Ordovician of McAdam's Hill is encountered, the uppermost beds of the formation being 4000 ft below the main *Monograptus-Baragwanathia* beds.

### The Matlock Formation

The Matlock Formation is here defined as including all the strata overlying the uppermost black slates of the St Clair Formation, upwards in the Woods Point Rd Section at Matlock to its own Unit 3, the Oaks Grit. This formation thus includes the strata formerly called the *Monograptus-Baragwanathia* Beds by Harris and Thomas and totals 5000 ft in thickness.

#### Unit 1

The basal unit of the Matlock Formation consists of 3000 ft of unfossiliferous sediments, overlying the uppermost black slates of the St Clair Formation. Bluish slates are prominent in the lower beds, together with blue-yellow claystones and greenish siltstones which increase towards the top of the unit. The uppermost beds

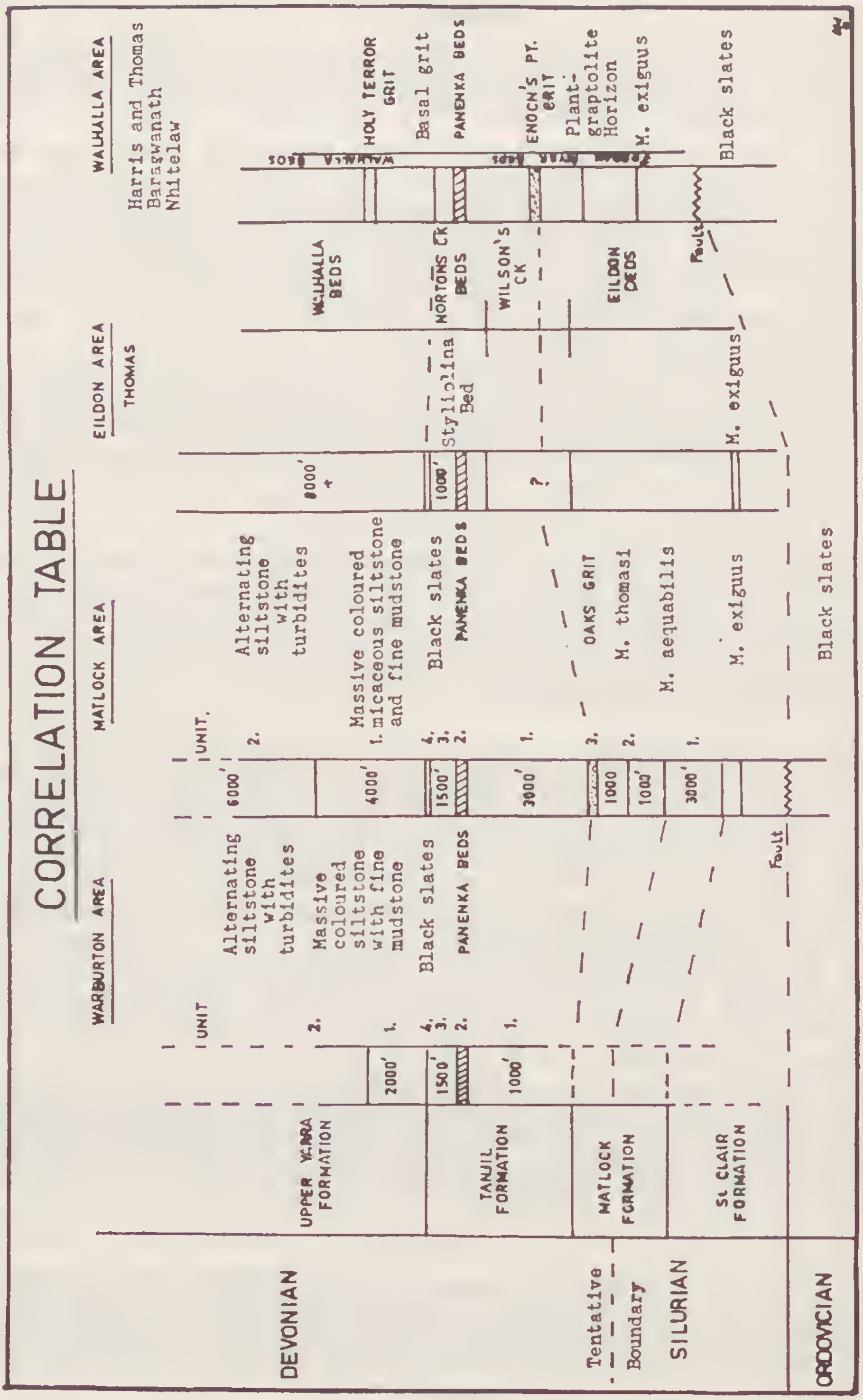
CORRELATION TABLE
WARBURTON AREA
MATLOCK AREA
EILDON AREA
THOMAS
WALHALLA AREA
Harris and Thomas
Baragwanath
Whitelaw
DEVONIAN
Tentative Boundary
SILURIAN
ORDOVICIAN
UPPER YARRA FORMATION
TANJIL FORMATION
MATLOCK FORMATION
St. CLAIR FORMATION
UNIT
2000'
1500'
1000'
Alternating siltstone with turbidites
Massive coloured siltstone with fine mudstone
Black slates
PANENKA BEDS
Fault
UNIT.
6000'
4000'
1500'
3000'
1000
1000'
3000'
Alternating siltstone with turbidites
Massive coloured micaceous siltstone and fine mudstone
Black slates
PANENKA BEDS
OAKS GRIT
M. thomasi
M. aequabilis
M. exiguus
Black slates
8000' +
1000'
?
Styliolina Bed
M. exiguus
WALHALLA BEDS
NORTONS CK BEDS
WILSON'S CK
EILDON BEDS
Fault
HOLY TERROR GRIT
Basal grit
PANENKA BEDS
ENOCH'S PT. GRIT
Plant-graptolite Horizon
M. exiguus
Black slates

FIG. 6.

of the unit are exposed only to the W. of the Oaks Clearing. Yellowish micaceous siltstones are prominent in the neighbourhood of the clearing itself, but exposures are incomplete and the exact sequence is difficult to determine.

### Unit 2

The base of this unit is marked by the incoming of *Monograptus aequabilis* (Pribyl) formerly identified as *Monograptus vomerinus*. This unit is 2000 ft thick and is overlain by the Oaks Grit. The shales of this portion of the unit commence to outcrop in the vicinity of the old 20 mile Quarry on the Woods Point Rd, and they extend westwards to the old 19 mile Quarry. At this locality the former are overlain by strata containing *Monograptus thomasi* Jaeger, formerly identified as *Monograptus uncinatus* together with *Baragwanathia* plants and formerly known as the *Monograptus-Baragwanthia* beds. As far as could be ascertained *Baragwanathia* does not occur in Unit 1.

The rocks of this age originally attracted world-wide interest when *Monograptus* and *Baragwanathia* specimens were discovered on the same slab of rock. At this time, they were thought to be of Middle Silurian age, but recent determinations of the graptolites accompanying the plants and those at the old 20 mile Quarry indicate a Lower Devonian age for the plants. In the recent survey of this area the *Baragwanathia* plants were not found below the base of Unit 2 or above the Oaks Grit, Unit 3 of the Matlock Formation.

Unfortunately the exposures of fossiliferous strata within this Unit 2 have been largely destroyed in recent roadmaking works in the area.

### Unit 3 (Oaks Grit)

The uppermost unit of the Matlock Formation is the Oaks Grit, 50-100 ft in thickness. It outcrops in a shallow road cutting about ½ mile W. of the Oaks Clearing. The member also repeats on the W. limb of the Oaks Syncline, nearly ⅝ mile W. of the Forest Camp, near the site of an old timber mill on the N. side of the Woods Point Rd. The repeat on the W. limb of the Forest Camp Anticline could not be found, but a band of coarse sandstones between the 19 and 20 Mile Quarries could represent a lithofacies change.

This Oaks Grit contains fragmentary corals and brachiopods with numerous calcareous particles and lithic fragments with subangular to subrounded form. This grit could be the same age as that mapped by Thomas (1942) at Enoch's Point to the N. of the present area as the basal grit of the Walhalla Group; there it is underlain by *Monograptus* slates.

## Tanjil Formation

These beds are an extension of the Tanjilian series defined by Chapman (1924) when he selected localities at Mt Matlock and on the Tanjil R. in defining the formation. Some confusion later arose when Gill (1941) selected the beds found by Whitelaw on the spur between the B.B. Ck and the Jordan R. as the type area for his Jordanian Series. Harris and Thomas (1942) produced detailed sections which showed that Gill had selected the extension of the same beds as those used by Chapman in his original definition; hence the term Jordanian was rejected.

The Tanjil Formation is here defined to include the original beds of Chapman's Tanjilian Series (the present Unit 2) and extended to all the strata overlying the Oaks Grit of the Matlock Formation and upwards to the top of the black slates of Unit 4 of this Tanjil Formation.

The total thickness is 4500 ft in the Matlock area, while only about 2500 ft is exposed in the Reefton area.

### Unit 1

Overlying the Oaks Grit Member of the Matlock Formation are 3000 ft of unfossiliferous sediments. They consist of highly coloured silstones and fine sandstones in shades of yellow, pink, red, and brown. They are commonly observed in the material turned up by roadworks on the Woods Point Rd between 2·5 and 3·5 miles E. of Monty's Camp. The prominent colours of the rocks and the general predominance of micaceous minerals in the hand specimen makes them distinctive.

### Unit 2

These beds, with their fauna of brachiopods and 'pteropods', have long been recognized as an important marker in the Siluro-Devonian sediments of Victoria. McCoy (1879) and Chapman (1905) gave descriptions of *Panenka* and *Tentaculites* respectively. Gill (1942) gave a comprehensive account of the occurrence of *Styliolina*, both on its own and in association with the above species. These '*Panenka* Beds' form one of the most important marker horizons in the area. They contain *Panenka gippslandica* and *Panenka planicosta* with abundant specimens of *Styliolina fissurella, Nowakia matlockiensis*, and orthoconic nautiloids. The *Panenka* Beds vary from 20-100 ft in thickness and have been proven in this survey to be a most reliable marker.

### Origin of the *Panenka* Beds

A detailed study of the plant remains and the *Panenka* and *Styliolina* shells has shown that they usually accompany a marked change in sedimentation. The sediments show a turbidite origin with graded bedding, convolute bedding, lithic fragments, flute casts, and other indications of current deposition. Further, the concentration of these fossils in very large numbers is interpreted as due to a catastrophic event in the sedimentation history of the geosyncline. While the fossils are thought to have a longer time range than the time represented by the thickness of these beds, the fact remains that, for some reason, they were exterminated in enormous numbers at this time.

It is concluded, therefore, that the *Panenka* Beds and associated plant horizons of Unit 2 of the Tanjil Formation were deposited by the action of turbidity currents related to folding in this portion of the geosyncline. It is envisaged that the turbulent, muddy conditions were responsible for exterminating the shelly fossils in large numbers and the turbidity current deposited the shells and plants above the initial graded bed of the deposit, relatively close to the change of sedimentation.

### Unit 3

This unit overlies the *Panenka* Beds and varies from 500-1000 ft in thickness. As with all the other major units, the greater thicknesses occur in the E. of the area, in the Monty's Camp Syncline. The lower 100 ft of the unit contains the beds with localized fragmentary brachiopod faunas listed by Gill (1941). The fossiliferous layers are restricted to the Reefton and Upper Yarra Dam areas, and were thought by Gill to be equivalent to horizons in the Yering Group at Lilydale.

The entire unit is unfossiliferous except for the brachiopod bands, and shows turbidite origin with graded bedding, lithic fragments, and current bedding.

### Unit 4

This unit consists of black slates and streaky blue and white siltstones 100-200 ft thick occurring approximately 1500 ft above the *Panenka* Beds of Unit 2. The author regards this Unit 4 as the equivalent of basal grits and conglomerates of the

Walhalla Synclinorium which are not present in the sections at Matlock or Warburton. These basal grits are now considered to be above the base of the Devonian (cf. addendum in Philip 1962; also recent identification of graptolites from the Matlock Formation, Jaeger MS.).

These black slates outcrop on the Yarra Track, approximately 1½ miles past Monty's Camp. They are seen again in a short outcrop on the Old Woods Point Rd below the Gooseneck. The same horizon reappears on Boundary Rd, SE. of the fire tower turnoff, while a similar rock type occurs in a cutting on the Yarra Dam Rd W. of Braham's Ck Cutting.

### Walhalla Group

This group of sediments is well known from the Walhalla Synclinorium to the E. of the present area. The maximum thickness of 10,000 ft is exposed in the Monty's Camp Syncline; the thicknesses appear to be considerably less in the W. at McMahon's Ck where less of the section is preserved.

The Walhalla Group in the Warburton-Matlock area is represented by the Upper Yarra Formation.

### Upper Yarra Formation

The Upper Yarra Formation is here defined as including all the strata overlying Unit 4, the Black Slate member of the Tanjil Formation, extending upwards to the top of the Monty's Camp Syncline. These beds are the youngest preserved in the Warburton-Matlock area.

#### Unit 1

The greatest thickness (4000 ft) of these sediments is developed on the Upper Yarra Track beyond Monty's Camp, overlying the black slates at the top of the Tanjil Formation. The rock types are predominantly coarse to fine massive siltstones interbedded with occasional fine claystones. The claystones are mostly yellow to grey in colour, while the siltstones are mainly pink with shades of orange to yellow. There is abundant evidence of turbidity current deposition, with flute casts, cross bedding, current bedding, convolute bedding, etc.

The Unit 1 reaches its maximum thickness in the vicinity of Monty's Camp and diminishes towards the W.; in the Braham's Ck region of E. Warburton it is less than 1000 ft thick.

In the E., the top of the formation is marked by a prominent plant (*Hostimella*) band in a quarry on the N. side of the Woods Point Rd, 1½ miles E. of Monty's Camp. The rock is a hard greenish black siltstone. The quarry has been closed as it lies in portion of the Upper Yarra Catchment, but considerable quantities of broken stone still remain.

At Braham's Ck, Reefton Spur Rd, and on the Yarra Track beyond Cumberland Junction, the plant band occurs but is not as prominent. Here the sedimentation changes to the rapidly alternating claystones and siltstones of the overlying Upper Yarra Formation, Unit 2.

#### Unit 2

These sediments reach a maximum preserved thickness of 4500 ft at Monty's Camp and between the Cumberland and the Dug Out on the Yarra Track. There is less than 1000 ft of this unit in the Braham's Creek Syncline.

The formation is characterized by rhythmically alternating claystones and siltstones, except in the basal beds of the formation on the E. limb of the Monty's Syncline. Here the siltstones are up to 3 ft thick, whereas the average thickness for both sediments in the other outcrops is of the order of 3-9 in.

## Sedimentology

The general evidence from the scanty fossil record of the area is that the Silurian and Devonian strata were the result of deep water deposition.

The older sediments of the St Clair and Matlock Formations in general are evenly bedded and show little or no evidence of the action of turbidity currents as a deposition mechanism. In contrast to this, the overlying sediments of the Tanjil Formation and the Upper Yarra Formation show increasing effects of current deposition towards the top of the section. The sudden appearance of current bedding and directional structures in the strata above Unit 1 of the Tanjil Formation is interpreted as marking the commencement of fold movements in this portion of the Siluro-Devonian geosyncline of Central Victoria.

It is envisaged that, as the fold movements began to take effect, portions of the ocean floor began to tilt and alter in level, resulting in much of the sediment being resorted.

### Detailed Sediment Structures

Details of the palaeocurrent directions were observed in many parts of the area. These were assessed from the clearly defined structures of cross bedding, current bedding, ripple marks, and other directional structures. In almost all localities in which the direction of sedimentation was assessed, the currents were found to originate in the W. This is interpreted as indicating that the direction of slope of the ocean floor at the time was towards the E. and is attributed to the early stages of formation of the Upper Yarra Anticlinorium, at present occupying the W. half of the section.

Rapid changes of texture are observed in many localities, involving changes from very fine mudstones to coarse sandstones. It is commonly noticed that the mudstone is overlain by a graded sandstone, and that the interface between the two sediments shows the influence of a moving current through structures resembling flow casts. At localities F.7, 8, and 9 on lower Boundary Rd, a dark varve-like shale is abruptly overlain by a streaky bluish white siltstone with plant fossils. Similar examples were collected from other localities. In all these cases there is an abrupt change of grain size, together with a change from varve type bedding in the shale to irregular contorted bedding in the sandstones, passing upward into graded siltstone. Graded siltstones commonly overly very fine mudstones, with mud pellets close to the interface.

Varve-like slates are represented widely in the area, and characteristically occur below the level of the *Panenka* Beds in the Tanjil Formation.

The inclusion of mud pellets in coarser sediments such as siltstone is a fairly common occurrence. These pellets have the composition of dark mudstone and are commonly enclosed in coarse micaceous siltstone showing only vague bedding. The pellets themselves usually have no bedding structures, but occasionally vague contorted bedding is noticed. They vary in shape from elliptical to a disc or saucer shape, and rarely exceed an inch in diameter.

It is concluded that the mud pellets represent blebs of the underlying layer of sediment which have been caught up in a turbidity current by the turbulence and swirling motion of its particles. They have a composition representing that of the finer bed.

Examples of current bedding are noticed at all stratigraphic levels in the section but they are extremely well marked in the Upper Yarra Formation. At lower stratigraphic levels in the Matlock and Tanjil Formations only an occasional layer shows current bedding, but in the youngest Upper Yarra Formation almost every layer shows this structure.

A blotchy or mottled appearance is widespread in the sediments of the Tanjil Formation. It consists of coloured lenses and streaks of white, blue, grey, green, and pink in sediments of the siltstone type. It was originally thought to be a differential weathering or leaching effect, but many of the specimens show a difference in grain size between the different coloured portions. The shape of the blebs and lenses and the difference in the grain size suggest an improper mixing of two sediments rather than the differential weathering of one sediment.

Several noteworthy examples of convolute bedding were recorded. In each case the convolutions were outlined in a white siltstone and the bedding layers were clearly marked by dark blue to black layers, showing folds overturned in one direction. The individual convolutions were up to 2 in. in width and 1 in. in height. Sawn sections of this siltstone from locality S.10 clearly illustrate this structure (Pl. 35).

## Significance of Palaeocurrent Directions

The two lowest formations in the stratigraphic column, namely the St Clair and Matlock Formations, show no strong indications of source direction for their material. These formations consist of well sorted sediment showing even bedding and indicating a deep water environment. Furthermore, since there is no positive evidence for a shallow water source for the sediment to the immediate W. of the area, it is concluded that the apparent currents and sediment structures are the result of sediment movement on the E. limb of the Walhalla Anticlinorium during

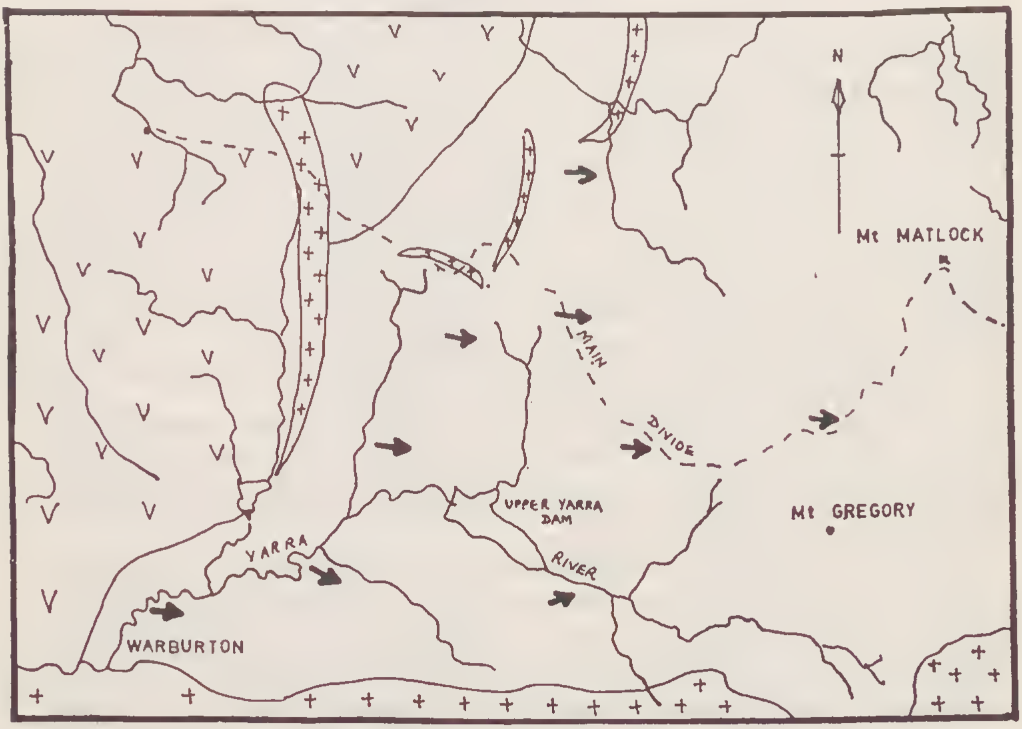


FIG. 7—Palaeocurrent Directions.

its initial stages of formation. The final conclusions will depend on the accurate structure and sedimentation studies at present being conducted in nearby areas.

GENERAL

The sedimentation record for the entire area shows a predominance of fine grained material with only a few medium coarse members. The general conclusion is that the present area represented the deep water portion of the Siluro-Devonian Geosyncline of East-Central Victoria.

The oldest sediment, the St Clair Formation, consists of fine black carbonaceous shales and mudstones of deep water origin, indicating an undisturbed environment. The overlying Matlock Formation has sediments with grain size up to that of medium coarse siltstone with one coarse member, the Oaks Grit.

The general grade of micaceous siltstone is interrupted by a band of dark slates in the Tanjil Formation overlying the Matlock Formation. The material above this, in the overlying Upper Yarra Formation, is of uniform siltstone grade.

There is a dramatic change in the sediment structure with the introduction of a current depositional environment in the upper Tanjil Formation and the overlying Upper Yarra Formation. It has already been recorded that this change is believed to have a tectonic origin and to account for the limited concentrations of otherwise widely distributed fossils such as *Styliolina* and *Hostimella* type plants.

It is doubtful whether all these sediment structures and the distribution of fossil material can be attributed to the action of turbidity current but, pending further investigation, this seems the most likely explanation.

## Palaeontology

In the course of the present survey some 70 fossil localities were located and recorded. The location and fossil content of these localities, together with those previously known, are summarized in Table 1. Some of the earlier recorded material was not accompanied by accurate descriptions of the localities and was difficult to trace; other localities were found to be overgrown or destroyed, and these have been marked on the map as close as possible to the original location.

It should be noted that well known localities on the Yarra Track, known formerly as the 18 mile, 19 mile, and 20 mile quarries, have been almost completely destroyed by recent roadworks. The mileages were originally measured from McVeigh's Hotel which is now submerged in the Upper Yarra Dam. It has been established that the Monty's Camp is 15·5 miles from the former site of McVeigh's, along the disused old Woods Point Rd, and mileages were adjusted from this point.

The general unfossiliferous nature of the sediments made correlation difficult, but certain well defined marker horizons could be mapped.

The reliability of the *Panenka-Styliolina* beds, Unit 2 of the Tanjil Formation, was consistently demonstrated in this survey. While the time range of these fossils is known to be much longer than that represented by their occurrence here, it remains that some catastrophe has caused their concentration in this unit, making them a very reliable marker in mapping.

The beds containing the abundant *Hostimella* plant remains are found to be closely associated with the *Panenka-Styliolina* beds and, being considerably thicker, they are a useful guide to the latter. The majority of the *Hostimella* plants were found between the levels of 500 ft above or below the *Panenka* beds. There is one exception—the concentration of these plants in a limited band in the overlying Upper Yarra Formation on the Yarra Track past Monty's Camp.

The band of fragmentary brachiopod material recorded by Gill (1942) near

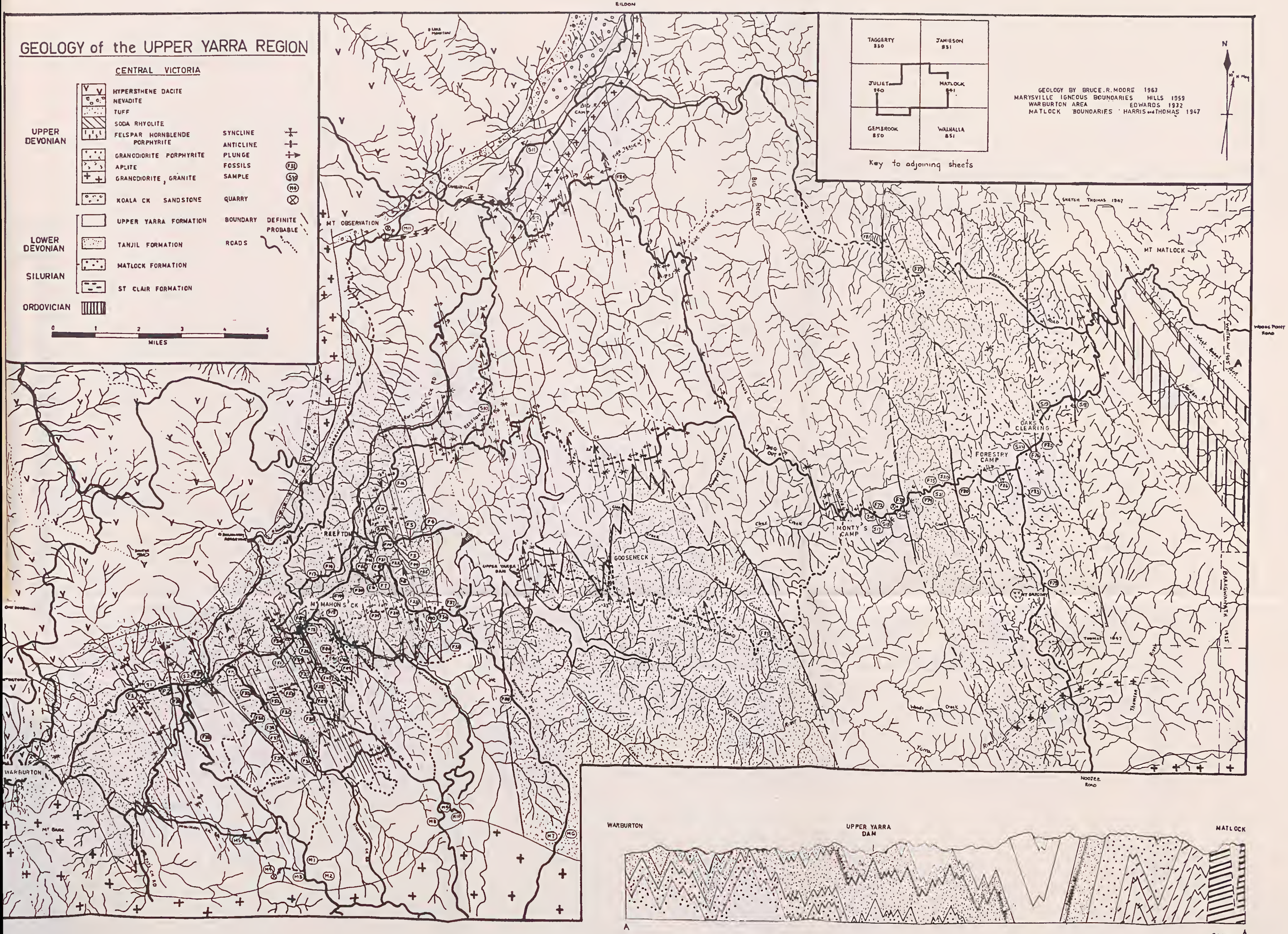


Fig. 8—Geological Map.

## Table 1

### *Upper Yarra Fossil Localities*

| No. | Locality | Plant remains indet. | *Pachytheca* sp. | *Taeniocrada dechenianus* | *Hostimella* sp. | *Hedeia corymbosa* | *Zosterophyllum australianum* | *Ceratiocaris* sp. | Orthoconic nautiloids indet. | *Tentaculites* sp. | *Nowakia matlockiensis* | *Styliolina fissurella* | *Hyolithes* sp. | *Coleolus aciculum* | *Zygospira* sp. | *Hercynella* sp. | *Posidonomya* sp. | *Paracardium* ? sp. | *Paracardium filosum* | *P.* n. sp. | *P. planicosta* | *P. gippslandica* | *Panenka cingulata* | *Lunulicardium antistriatum* | *Actinopteria* sp. | *Orbiculoidea* sp. | *Cyrtina* sp. | *Chonetes* n. sp. | *Atrypa* sp. | Tanjil Formation: *Athyris* sp. | *Monograptus aequabilis* | *Yarravia oblonga* | *Baragwanathia longifolia* | Ceratiocaridae indet. | *Pterygotus* sp. | Orthoconic nautiloids | Matlock Formation: *Monograptus thomasi* | St Clair Formation: *Monograptus* sp. (cf. *exiquus*) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| F 1 | Main Rd near Braham's Ck Rd | × | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| F 2 | Main Rd near Braham's Ck Rd | | | | × | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| F 3 | Main Rd Quarry Yankee Jim Ck | × | × | | × | | × | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| F 4 | Drainage Tank Yankee Dam | | | | × | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| F 5 | Main Rd before Yarra Dam | | | | | | | | × | × | ? | × | | | | | | | | | | | | | | | | | | | | | | | | | | |
| F 6 | Lower Boundary Rd | | | | | | | | | | | × | | | | | | | | | | | | | | | | | | | | | | | | | | |
| F 7 | Lower Boundary Rd | | | | | | | | × | | ? | × | | | | | | | | | | | | | | | | | | | | | | | | | | |
| F 8 | Lower Boundary Rd | × | | | | | | | | | | | | | | | | | | | × | | | | | | | | | | | | | | | | | |
| F 9 | Lower Boundary Rd | × | | | | | | | × | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| F10 | Lower Boundary Rd | | | | × | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| F11 | Reefton Spur Rd | | | | × | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| F12 | Reefton Spur Rd | | | | × | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| F13 | Crush Zone Main Rd, Reefton | | | | × | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| F14 | Aqueduct Yankee Jim Siphon | | | | × | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| F16 | Armstrong's Ck Rd | × | | | × | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| F17 | Big Bill's Rd off Armstrong's Ck Rd | × | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| F18 | Aqueduct McMahon's Ck | × | | | × | | | | | × | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| F19 | Aqueduct McMahon's Ck | × | | | × | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| F20 | Aqueduct McMahon's Ck | × | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| F21 | Lower Boundary Rd | | | | | | | | × | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| F22 | Lower Boundary Rd | | | | | | | | × | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| F23 | Fire Track off Boundary Rd | × | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| F24 | Fire Track off Boundary Rd | | | | | | | | | | | × | | | | | | | | | | | | | | | | | | | | | | | | | | |
| F25 | Fire Track off Boundary Rd | | | | | | | | | | | × | | | | | | | | | | | | | | | | | | | | | | | | | | |
| F26 | Muddy Ck Aqueduct Siphon | × | | | × | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| F27 | Muddy Ck Rd | × | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| F28 | Muddy Ck Rd | × | | | × | | | | | × | | × | | | | | | | | | × | | | | | | | | | | | | | | | | | |
| F29 | Muddy Ck Rd | × | | | × | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| F30 | Muddy Ck Rd above Trevena's Rd | × | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| F31 | Starvation Ck Rd | | | | | | | | × | | | × | | | | | | | | | × | | | | | | | | | | | | | | | | | |
| F32 | Starvation Ck Rd | | | | | | | | × | | | × | | | | | | | | | | | | | | | | | | | | | | | | | | |
| F33 | Starvation Ck Rd | | | | × | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| F34 | Main Rd O'Shannassy Turnoff | | | | × | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| F35 | Braham's Ck Rd | × | | | × | | | | | | | × | | | | | | | | | | | | | | | | | | | | | | | | | | |
| F36 | Braham's Ck Rd | × | | | × | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| F37 | Patrol Rd off Starvation Ck Rd | | | | × | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| F38 | Patrol Rd off Starvation Ck Rd | × | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| F39 | Patrol Rd off Starvation Ck Rd | | | | × | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| F40 | Fire Track between Muddy & McMahon's | | | | × | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| F41 | Fire Track between Muddy & McMahon's | | | | | | | | × | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| F42 | Fire Track between Muddy & McMahon's | | | | | | | | × | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| F43 | Aqueduct before Reefton | | | | | | | | | | | × | | | | | | | | | × | | | | | | | | | | | | | | | | | |
| F44 | Yankee Jim Ck | | | | | | | | | | | × | | | | | | | | | × | | | | | | | | | | | | | | | | | |
| F45 | Yankee Jim Ck | | | × | × | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| F46 | Aqueduct above Reefton | | | | | | | | | | | | | | | | | | | | | | | | | | | × | | | | | | | | | | |
| F47 | Fire Track off Muddy Ck Rd | | | | | | | | × | | | × | | | | | | | | | × | | | | | | | | | | | | | | | | | |
| F48 | Fire Track off Muddy Ck Rd | × | | | × | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| F49 | Fire Track off Muddy Ck Rd | × | | | × | | | | | | | × | | | | | | | | | | | | | | | | | | | | | | | | | | |
| F50 | Main Rd near Muddy Ck | | | | | | | | × | | | × | × | × | × | × | | | | | | | | | | | | | | | | | | | | | | |
| F51 | Main Rd near Muddy Ck | | | | | | | | × | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| F52 | Trevena's Rd near Starvation Ck Rd | | | | | | | | × | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| F53 | Trevena's Rd | × | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| F54 | Main Rd before Muddy Ck | × | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| F55 | Crooked Ck | | | | × | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| F56 | Boundary Rd before Fire Tower | | | | | | | | | | | × | | | | | | | | | | | | | | | | | | | | | | | | | | |
| F57 | Boundary Rd before Fire Tower | | | | × | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| F58 | Fire Track from Boundary Rd | | | | × | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| F59 | Upper Boundary Rd | | | | × | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| F71 | Main Rd Starvation Ck Bridge | | | | | | | | × | × | | × | | | | | | | | | | | | | | | | | | | | | | | | | | |
| F72 | Woods Pt Rd 1m past Monty's Camp | × | | | × | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| F73 | Woods Pt Rd 1½m. past Monty's Camp | × | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| F74 | Woods Pt Rd 2½m. past Monty's Camp | × | | | × | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| F75 | Woods Pt Rd Old 18m. Quarry | | | | × | × | × | | × | × | | × | | | | | | | | | × | × | | | | | | | | | | | | | | | | |
| F76 | Clearing 1m. past Forestry Camp | × | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| F77 | Frenchman's Spur Rd | | | | | | | | | | | × | | | | | | | | | | | | | | | | | | | | | | | | | | |
| F78 | Main Rd and Muddy Ck Rd | | | | | | | | × | | | × | | | | | | | | | | | | | | | | | | | | | | | | | | |
| F79 | Green Hut Noojee Rd, Mt Gregory | × | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| F80 | Woods Pt Rd, Old 19m. Quarry | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | × | × | × | × | × | × | |
| F81 | Frenchman's Spur Road | × | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| F82 | The Oaks Clearing | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | × | | | | | |
| F83 | 1m. S. of Forestry Camp | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | × | |
| F84 | Yarra Track near Fire Track No. 2 | | | × | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| F85 | 5½m. past Gooseneck Old Woods Pt Rd | | | | | | × | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| F86 | Old 20m. Quarry | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | × | × | × | | | × | | |
| F87 | Between Muddy Ck and McMahon's Ck | | | | | | | | | | | | | | | × | | | × | | | | | | × | × | × | | × | | | | | | | | |